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Effects of Hearing Loss on General Cognitive Health and Social Auditory Lifestyle within the Older Population

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Abstract

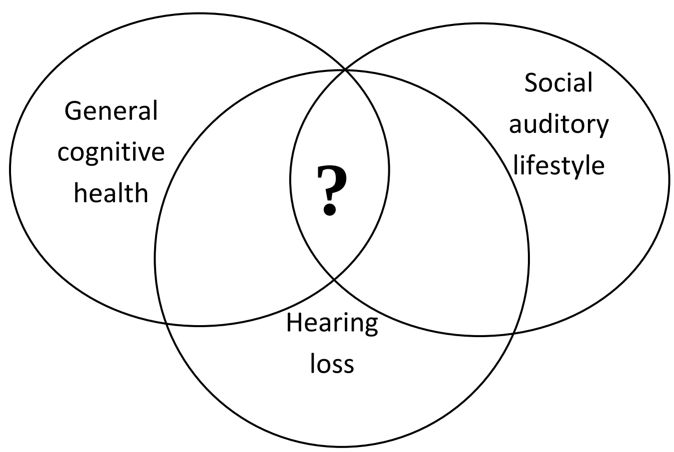
Hearing loss is a common medical condition associated with the elderly. Its impact on general cognitive health has been extensively studied, along with its association with social auditory lifestyle. Hearing loss has been associated with a decline in both aspects (Lin, 2011a; Wu and Bentler, 2012), however, studies involving all three of these factors have yet to be performed. Further research is needed to encompass how these three facets, when combined, affect the elderly population. A literature review of 21 articles was conducted in order to reveal how hearing loss is associated with general cognitive health and social auditory lifestyle.

Introduction

Hearing loss (HL) is one of the most common health conditions among people aged 65 years or older. The general public may be aware that hearing loss (HL) is common as one ages, however, they may not fully comprehend the entirety of its impact. It is imperative to interpret how HL affects the older population (65+ years) because demographics are significantly changing at the global level. It is anticipated that this group will "...triple by the midcentury, from 516 million in 2009 to 1.55 billion in 2050" (U.S. Bureau of the Census, 2007). This projection highlights the critical need for further care and understanding of hearing loss and its repercussions.

Recent research in the field of audiology has examined how hearing loss is associated with other factors experienced by the older population. For example, how cognitive health and social auditory lifestyle relate to hearing loss within the older population. According to Lin et al., "...hearing loss is independently associated with cognitive decline and incident cognitive impairment in community-dwelling older adults" (2013). Hearing loss is also known to regularly affect social auditory lifestyle. A more recent study confirmed that older listeners with a hearing impairment have less frequent listening demands compared to younger listeners (Wu & Bentler, 2012).These interrelationships may be visualized in Figure 1.

Figure 1: *Interrelationships between hearing loss, general health cognition, and social auditory lifestyle*



There are numerous studies which expose the potential interaction between hearing loss + general cognitive health and hearing loss + social auditory lifestyle. However, further research is still necessary to determine the relationship between all three factors: hearing loss + cognition + social auditory lifestyle. The purpose of this document is to review recent literature regarding how hearing loss is associated with general cognitive health and social auditory lifestyle.

Methodology

Relevant literature was recently identified using the database Cumulative Index to Nursing and Allied Health Literature (CINAHL) Plus with an advanced search. Designated limits were "peer-reviewed" and "English."Keywords used were "hearing loss in elderly+cognition+aging" "hearing loss in elderly+cognition" "hearing in elderly+social lifestyle" "cognitive decline in older adults+hearing" "auditory lifestyle+demands" and "auditory ecology." There were a total of 31 hits. Articles were first excluded by title, then by abstract, then by text, and finally by any duplicates noted. This system narrowed down the articles for inclusion to a total of five. Additional resources were identified using the Resound GN Audiological Library. This library consists of Danavox Symposia (ranging from the 1st-21st Symposium), the International Symposia on Auditory and Audiological Research (ISAAR) (22nd-26th), Scandinavian Audiology (volumes ranging from the years 1972-2001), various Scandinavian Audiology Supplements, Journal of Speech and Hearing Research (Volumes 1-47), and the Journal of Auditory of Research (Volumes 1-27). Ultimately, a total of 4 articles were selected for review using the method of exclusion previously described. In addition, a total of 12 articles were also included as they were identified through a screening of sources contained in the previous articles. Overall, a grand total of 21 articles were accepted for review and they are labeled with an asterisk in the References section.

Hearing Loss and Cognition

Hearing loss and its association with cognitive decline has been a topic of interest in numerous fields. Both conditions are known to have negative effects and can be debilitating to an individual. Deficits in either area could lead to difficulties with communication, lack of interest in previous hobbies, isolation, and more. The need to better understand this relationship is imperative because it could lead to optimal management options in the future. The auditory and cognitive systems are so complex that their physiology is still not fully understood and the details of how one affects the other are not clear.

Hearing loss is common in the older population, with 44.9% of people in their 6th decade of life having some degree of impairment (Lin, Niparko, & Ferrucci, 2011b). A simplified understanding suggests hearing is supplied solely by the ears, when actually there is synergistic interaction of multiple structures. Also, the Ease of Language Understanding (ELU) model recognizes that communication requires not just hearing, but also listening and comprehension (Rönnberg et al., 2013). Auditory stimuli follow a complex and specific pathway from the ear to the brain. Deficits may take place at any point along the auditory system, which can lead to varying issues. There are countless reasons for these deficits to occur, but a simple reason may be due to the body's natural aging process. Several studies have evaluated how aging affects structures ranging from the periphery to central locations of the auditory system. Peelle and Wingfield (2016) explain that changes throughout these structures can contribute to what is known as an age-related HL (ARHL). Aging causes changes in the auditory periphery (e.g. outer hair cells and cochlear nerve axons), subcortex (e.g. spiral ganglion neurons, cochlear nuclei, superior olivary complex, various midbrain structures), and the auditory cortex (e.g. protein parvalbumin and myelin). There are a number of histopathological studies that describe even more specific structures that are affected by aging and the use of imaging studies provide a way to evaluate how ARHL creates changes in the central auditory system. For example, Lin et al. conducted a cohort study examining the difference of brain volumes between normal and hearing impaired subjects. The study included 126 participants ranging in age from 56-86 years. The participants' hearing sensitivity ranged from normal to severe in degree and were sensorineural in type. Magnetic resonance imaging (MRI) analysis revealed the participants with a hearing impairment had significant declines in volume of the whole brain and regional areas of the right temporal lobe. These findings have shown that peripheral HL is independently associated with changes in higher-order structures (2014). Recent MRI studies have confirmed changes of central auditory pathways in subjects with ARHL. According to Jayakody, Friedland, Martins, & Sohrabi (2018), a collection of these studies show "...that ARHL not only results in secondary pathophysiological changes in the central auditory pathway, but also in the areas of the brain that are not directly involved in processing auditory stimuli" (2018). Considering HL has been shown to affect various parts of the brain, this could be seen as further evidence of its role in cognitive decline.

Cognition could be considered an umbrella term. It envelops multiple processes that contribute to bodily function; it is the interface between an individual and their environment. A definition for cognition is "...the mental action or process of acquiring knowledge and understanding through thought, experience, and senses" (Cambridge Cognition, 2015). Cognition is how perception is made possible. According to Borchgrevnik (2003), sensory organs are what react to physical or chemical input from the environment; based on what stimulus they are hardwired to react to. This stimulus causes a message (nerve impulse) to be sent to the brain via nerve fibers, and the message is sent to the sensory organ's dedicated brain center. These sensory organs are paired with certain parts of the cortex, and this is referred to as being modality-specific. The cortex even ranks these modality-specific cortical areas into a type of hierarchy with different levels (primary, secondary, tertiary). Across the levels, these nerve fibers actually converge so that the brain can identify, sense, perceive, discriminate, and ultimately decode the message (2003). Other aspects of cognition include, but are not limited to: working memory, processing speed, encoding and retrieval of new information, arithmetic skills, and auditory/verbal memory (Borson, 2010). The brain must rely on these skills as it interprets countless messages throughout day.

Communication is how one connects to the outside world. It allows for relationships to form and to be able to participate in various activities. Communication is an innate ability, but it is a complex process that requires a lot of steps to be completed successfully. Schneider (2011) explains in order for someone to take part in a conversation, they need to be able hear the other talker, process the meaning of the message, store important information for later use, recall past information from the brain, and formulate a relevant response. Disruption to any part of this process could lead to communication breakdown in the conversation. Being able to perceive speech requires both auditory and cognitive abilities. Unfortunately, this integrated system is often disrupted in older individuals.

Schneider, Pichora-Fuller, and Daneman (2010) discuss how changes in the auditory system and cognition may affect spoken language comprehension. They explain the effects of age-related changes in cognitive processes on the comprehension of spoken language. For example, working memory, inhibitory control of unrelated stimuli, and deficits in processing speed can impact performance. However, testing for the interaction between the auditory and cognitive systems on speech understanding can be quite complicated in elderly adults. Some testing considerations include: what stimuli are appropriate and how to make testing represent natural listening tasks, such as multiple-talker conversations (Schneider, Pichora-Fuller, and Daneman, 2010). It is difficult to differentiate to what degree an impairment in hearing or cognition affects spoken language comprehension. A study by Jerger, Jerger, &Pirozzolo (1991) focused on this relationship. Participants were 200 elderly adults ranging in age from 50-91 years. The test battery included pure-tone audiometry and a variety of speech testing such as the synthetic sentence identification test (SSI), the speech perception in noise (SPIN) test, and the dichotic sentence identification (DSI) test. Cognition and IQ were assessed with the Weschler Adult Intelligence Scale-Revised (WAIS-R), Weschler Memory Scale (WMS), Boston Naming Test (BNT), Spatial Orientation Memory Test (SOM), Buschke Selective Reminding Test (BSRT), and the Four-Choice Visual Reaction Time Test. Results showed that both hearing loss and cognitive status significantly affects speech recognition in the elderly.

Associations

General cognition. Both hearing loss and cognition have become increasingly popular topics in the healthcare field because of growing awareness of their importance as one ages. Audiologic workshops are even being created so professionals may collaborate on how to approach such issues. For example, Lustig and Olson (2014) headed a hearing loss and healthy aging workshop that focused on how to healthily age while also having a hearing loss. Some topics in the workshop included current technologies being used for management, contemporary issues, and current hearing healthcare delivery models. These discussion groups are a beneficial way for medical professionals to be conscious of new research so that they can relay this information to their patients.

A growing number of studies have been issued to find a link between hearing loss and cognitive decline in the elderly population. Multiple studies were based on an observational cohort study called the Health, Aging and Body Composition (Health ABC) study. The purpose of the Health ABC study was to examine how healthy older individuals (aged 70-79 years at baseline) age. The study was designed to determine any risk factors that would lead to decline in function and the interrelationships between the factors involved. The longitudinal cohort was recruited from 1997-98 (NIH, 2013). The cohort consisted of 3,075 community-dwelling participants (men and female) and they were drawn from randomly sampled Medicare enrollees from Memphis, Tennessee and Pittsburgh, Pennsylvania (Deal et al., 2017). A large amount of health information was obtained from these participants. The health statuses were obtained via yearly clinical examinations and consistent six month phone calls over the course of six years. These six month phone call check-ups continued and annual exams occurred on the 8th and 10th year of the study. Also, more detailed health experiences relating to cardiovascular events, cancers, dementia, and other medical developments were collected. Follow-up with participants extended to 16 years. The last medical examination was conducted in 2011 and the mean age of the participants at this time was 86 years. Ultimately, a surplus of data was collected from the ABC Study, which has led to an expansion of related studies that have been contributing to the knowledge base (NIH, 2013).

One significant Health ABC study was able to show that hearing loss is independently related to cognitive decline in older individuals in a cohort study spanning over a 6 year period (Lin et al., 2013). This study included 1,984 older adults. Also, a baseline cohort group consisted of participants without a cognitive impairment using the Modified Mini-Mental State (3MS) $\geq$ 80. Hearing sensitivity was determined by a pure-tone average of 500-4000 kHz in the better-hearing ear. Cognition was evaluated using the Digit Symbol Substitution Test (DSST) and the 3MS for executive and global function, respectively. Results revealed people with a hearing loss had a 30-40% accelerated rate for cognitive decline compared to the participants who had normal hearing (Lin et al., 2013).

Another study showed similar results as the Health ABC studies (Lin, 2011a). Subjects' data was collected from the National Health and Nutritional Examination Survey (NHANES), cycles from 1999-2002 for subjects ranged in age from 60-69 years. Results from this study revealed lower working memory capacity (DSST) scores as hearing loss increased (Lin, 2011a).

Jayakody, Friedland, Eikelboom, Martins, and Sohrabi (2017) advocated for the use of an extensive test battery, including estimates of working memory capacity such as the DSST, for evaluating a hearing loss and its connection to cognition. The authors noted recent studies have used cognitive measures that rely significantly on verbal cues, which could be difficult for a subject with a hearing loss to accommodate. The DSST being a visual task side-steps this issue. This particular study included 119 participants, ranging in age from 45-85 years. Hearing sensitivity for these participants included 47 people with normal hearing (thresholds < 25 dBHL), 51 had a mild-moderate hearing loss (thresholds 26 to 55 dBHL), and 21 had a moderately-severe to profound (thresholds > 55 dBHL), hearing loss. The test battery evaluated tests of hearing ability (air and bone conduction thresholds at 0.5-8kHz), non-verbal cognition functions (Cambridge Neuropsychological Test Automated Battery, Motor Screening Task, Attention Switching Task, Delayed Matching to Sample, Paired Associates Learning, Verbal Recognition Memory, and Spatial Working Memory) and psychological status (Depression Anxiety Stress Scales [DASS-21]). Results confirmed a significant association between hearing loss and cognition, in particular with working memory tests. This study also showed that non-verbal cognitive tests should be considered when testing people with a post-lingual hearing loss. These non-verbal tests also showed a significant correlation.

Dementia. Considering hearing loss has been independently associated with cognitive decline, researchers wanted to assess its relationship with specific impairment of cognition, namely dementia. The World Health Organization describes dementia as a syndrome of cognitive deterioration. Dementia can be static or progressive in nature. Generally, individuals will develop difficulties with "memory, thinking, orientation, comprehension, calculation, learning capacity, language, and judgment" (2017). The effects of dementia may vary greatly among individuals. Early stages of dementia can include basic forms of forgetfulness or becoming lost in a familiar neighborhood. Middle stage symptoms include forgetting names, requiring help with personal grooming, and physical wandering. Late stages of dementia entail severe memory loss, where the need for total dependency from others becomes apparent (World Health Organization, 2017). There are currently an upwards of 47 million people affected in the world. By 2050, 131 million people will have dementia and an expected trillion dollar cost for the condition by 2018 (Prince, Comas-Herrera, Knapp, Guerchet, & Karagiannidou, 2016).

Hearing loss has been associated with cognitive decline and dementia causes deficits in cognition. So, it is only natural for researchers to examine the relationship between hearing loss and dementia. Deal et al. (2017) examined whether hearing loss increases the risk for developing dementia over a period of 9 years. The authors were members of the Health ABC Study Group, expanding on Lin et al. (2013). They also found an association between hearing loss and cognitive decline. Considering HL is treatable and easily identifiable, it would be beneficial to know if hearing loss is a precursor to cognitive decline so preventative measures may be implemented. The study included 1,889 participants that were obtained from the 1997-1998 Health ABC Study, all of which were dementia-free in the first year of recruitment. These individuals ranged in age from 70-79 years. The participants were compared to normal hearing participants' void of any other risk factors that might affect their health. Data from the Health ABC Cognitive Vitality Sub-study (CVS) was included in the study's complementary analysis, to determine if HL is associated with cognitive decline by examining memory, perceptual, and processing speed. Neurocognitive assessments (CVS) included: Buschke Selective Reminding Test (verbal memory), the Boxes Test (psychomotor speed), Digit Copying Test (psychomotor speed), the Pattern Comparison Test (perceptual speed), and the Letter Comparison Test (perceptual speed). Hearing sensitivity was determined by a pure-tone average (PTA) of 500-4000 kHz in the better-hearing ear. Results revealed 229 participants had developed incident dementia within the 9 years of the study. A robust association was found between people with a moderate/severe HL and dementia (55% increased risk), compared to normal hearing participants. Also a linear trend was observed between pure-tone average (PTA) and hazard ratio of incident dementia (2017).

Lin, Metter, O'Brien, Resnick, Zonderman, and Ferrucci (2011c) performed a study that assessed the relationship between HL and dementia. This prospective study included 639 participants from the Baltimore Longitudinal Study of Aging. These participants' audiometric thresholds and clearance of dementia was obtained in 1990-1994. Adjustments were made (using Cox proportional hazard models) for other factors such as age, sex, race, education, diabetes, smoking and hypertension. Through 11.9 years of follow-up, 58 participants were diagnosed with dementia. The ratio for incident all-cause dementia increased as the severity of a participant's HL increased.

Alzheimer's disease. A common form of dementia is Alzheimer's disease (AD). According to the World Health Organization, it may contribute to 60-70% of cases. AD interferes with cognitive abilities, especially memory. (2017). Studies have also attempted to link hearing loss with AD. In Albers et al. (2015), the National Institute on Aging held a workshop to better understand how neuropathological changes to sensory and motor systems may lead to AD as individual's age. The auditory system was one of the sensory systems that were investigated, and an interesting note they mentioned was the prevalence of people with ARHL and AD is still not known. Gates, Anderson, McCurry, Feeney, and Larson (2011) conducted a cohort study to discover if central auditory dysfunction (CAD) is a precursor for AD. A total of 21 participants out of 274 were found to have AD post audiologic testing. The Dichotic Sentence Identification, the Dichotic Digits, and the Synthetic Sentence Identification with Ipsilateral Competing Message were administered. The central auditory test results were considered significantly poorer pre-onset in the group with AD, and it was concluded CAD is a precursor to AD. Neurophysiologic studies are an objective way to assess the central auditory system, so these are being used to compare ARHL to AD. Papaliagkas, Anogianakis, Tsolaki, Kokiakos, and Kimiskidis (2010) investigated the diagnostic role of CSF beta amyloid (1-42) and auditory related potentials (AERPs) in a range of cognitive impairments, including AD. This study included 53 participants who had a mild cognitive impairment. CSF beta amyloid (1-42) levels were tested via a lumbar puncture and they were administered neuropsychological and ERP examinations. CSF beta amyloid levels are positively correlated with AD. Eleven months later, 20 participants were re-examined, and 5 of them had progressed to having AD. Participants with AD had significantly lower beta amyloid (1-42) levels. Also, they had prolonged latencies and lower amplitudes of P300, however this was not significantly different from those with mild cognitive impairment.

Animal studies have also been used to examine the relationship between hearing loss and cognition. Animal studies are beneficial because many factors can be manipulated in comparison to humans. Wang, Ikonen, Gurevicius, Van Groen, and Tanila (2003) used mice to appraise the middle latencies of AEPs, which measures the function of the primary auditory cortex. Some of the mice tested were carriers of human amyloid precursor protein and presenilin-1 transgenes. Results exposed that these mice showed amyloid-β peptide (Aβ) pathology of the auditory primary cortex. A drawback of this study was the hearing of the mice was not evaluated. However, this information may be used to test for AD in the future. The concept of hearing loss as a precursor for AD is becoming more common. Continuing this compilation of information will help to providers to optimize diagnosis and treatment of AD. Albers et al. (2015) recommends future research is needed to further determine how peripheral/central auditory dysfunction can predict AD, using multiple approaches such as neuroimaging, genetic testing, and other biomarkers. Also, interventional studies of patients with both hearing loss and AD, being treated with audiologic rehabilitation, may better reflect the relationship between the two conditions.

Summary

There are millions of elderly individuals who are coping with an age-related hearing loss. This number is suspected to grow considerably over the next several decades. Numerous studies have confirmed that people with ARHL have communication issues, a reduction in brain volume, and pathophysiological changes to their central auditory pathways over time. Cognitive decline has also been associated with the elderly and its relationship to ARHL. ARHL has been shown to be significantly related to dementia and Alzheimer's disease. These issues with cognitive processing also have its effects on optimal speech perception. Hearing loss and cognitive decline are both conditions that have the ability to reduce a person's capacity to effectively communicate and quality of life. Further studies will be beneficial in determining if preventative intervention will help to alleviate the progression of these collective symptoms.

Social Patterns, Hearing Los and Auditory Lifestyle

There are current assumptions made about the elderly and their lifestyles. In general, people believe they live a relatively dormant lifestyle. However, these beliefs should be proven by objective evidence rather than by the stereotyping of a whole generation. Recent epidemiology studies are highlighting recent trends of the aging. According to Beers (2005) the population of people 65 years or older is expected to dramatically outpace the total population by 2040. This drift is in part due to higher life expectancy rates. For example, the average life expectancy is around 78 years, for people who were born in 2005. Compared to those born in 1950 who have a life expectancy of 68 years (National Center for Health Statistics [NCHS], 2007). A larger number of older individuals, who are assumed to be living longer than any other generation, are causing employers to think about retirement. The U.S. Bureau of Labor and Statistics reported that workers 65 years and older has increased 101% from 1977 to 2007 (2008). It seems that the elderly may be more active than they were previously. Numerous studies have been examining the auditory lifestyles of the elderly in order to better understand what they are experiencing. Accommodating to the needs of this large and active population be a high priority.

Social Patterns

Social science researchers have studied various theories on how the elderly age. Nussbaum, Pecchioni, Robinson, & Thompson (2000) stated "...that at the core of any successful attempt to adapt to biological aging is communication." Analyzing how communication changes in the elderly will help society to accommodate their needs. Less socially active lifestyles are one of the proposed reasons the elderly may report fewer listening demands. A theory to explain this pattern is known as the disengagement theory. Cumming, Dean, Newell, & McCaffrey (1960) proposed the disengagement theory and described it as an inevitable withdrawal of the elderly from society. The foundation of this theory suggests that the elderly will age most successfully if they are aware and accepting of this process. Whether this theory is considered accurate, finding insights within this theory may give perspective on current societal norms.

Palmore (1981) looked at social patterns in the elderly using data from the Duke Longitudinal Study. Their cross-sectional study included 200 participants (aged ≥ 50 years). People within the 50-54 year age range, 61-86% reported high social activity. Compared to people over 75 years old, only 8-27% reported high social activity. Palmore (1981) explains previous studies such as Cumming & Henry (1961) and the Duke Longitudinal Study report a decline in social activity, but not all types of social activity are reduced. For example, contact with friends and family, religious, volunteer, and political activity does not decline until the 8th decade of life. There is great variation among social activity patterns over time and there are even groups who have an increase in activity. Significant precursors for social activity will vary depending on the type of activity, primary being predicted by living with someone and secondary being predicted by higher social economic status and being a female. Men were found to have more primary group activities and women had more leisure, religious, and secondary group activities (1981). Overall, it is best not to make assumptions on someone's lifestyle; they may be coping with varying demands while having a hearing loss.

Assessments of Auditory lifestyle

Viewing how people expose themselves to various environments will help clinicians to guide them in their healthcare journey. Researchers and clinicians are often interested in a patient's ecology, or social auditory lifestyle, for many reasons. Hearing aid selection, programming options, as well as treatment plans should be tailored to an individual's lifestyle. Selecting the appropriate device, their settings, and rehabilitation options can all be based on how someone functions in the real-world. Before treatment may begin, this data must be obtained through various means.

Ecological approach. The study of how a person interacts within their own environment is known as human ecology. Taking on a person's perspective and analyzing their environment will provide relevant information on how to accommodate their needs. Borg (1998) explains this concept may be used in clinical audiology. A clinician is meant to find the of the problem cause (e.g. hearing loss), the consequences it may have on the patient, and how the problem is preventing the person from taking part in former activities that were enjoyed prior to the HL. Investigations implementing an ecologic approach take effort and creativity to accurately simulate the real-world in the laboratory, develop assessments that evaluate the afferent, central, and efferent functions of patients, and transform adaptive behavior in a dialogue format for testing. Ecology may offer a way for traditional audiometry to be combined with social and psychological dimensions (1998). Taking a holistic approach will allow more aspects of the patient's life to be taken into account, which will hopefully lead to better success.

Self-assessments. A way to obtain information about someone’s daily life is through subjective assessments. These tools have been developed to gauge the situations patients frequent throughout their day, and they are generally utilized to complement objective data. Current self-assessment scales used in clinic, prior to the selection of hearing aids: Hearing Handicap Inventory for the Elderly/Adult (HHIE/A), Abbreviated Profile of Hearing Aid Benefit (APHAB), Expected Consequences of Hearing Aid Ownership (ECHO), Client Oriented Scale of Improvement (COSI), Hearing Aid Selection Profile (HASP), Characteristics of Amplification Tool (COAT), and the Profile of Aided Loudness (PAL) (Mueller, Ricketts, Bentler, 2014). A section on auditory lifestyle is usually imbedded within these. There are other significant questionnaires to use. For example, Jensen and Nielsen (2005) had their participants fill out the Auditory Lifestyle and Demand Questionnaire (ALDQ) while within their various environments, to be compared to objective sound recordings throughout their day. Some researchers have developed their own questionnaires, but it is recommended to always use options that are validated. Also, the applications of daily journals have been favored in some studies (Wu & Bentler, 2012). These tools are found to be quite helpful when comparing information obtained through more objective means.

Self-assessments such as these have shown how much the elderly believe their hearing loss is impacting them. Wiley, Cruickshanks, Nondahl, and Tweed (2000) evaluate data from the Epidemiology of Hearing Loss Study (EHLS) for 3178 adults, aged 48-92 years. These individuals had their audiometric thresholds (250-20,000 Hz) and word recognition performances (Northwestern University Auditory Test No. 6 [NU-6]) in quiet and in noise were tested. They also administered the Hearing Handicap Inventory for the Elderly-Screening (HHIE-S). Results revealed the self-reported hearing handicap was higher for the younger participants compared to the older ones, after degree of hearing loss was controlled for. Another well-known study using the HHIE and HHIA showed similar results. Gordon-Salant, Lantz, Fitzgibbons (1994) also examined how age may affect self-perceived hearing disability among younger (18-40 years) and older (65-75 years) listeners with either normal hearing sensitivity or a mild to moderate HL. Analyses showed the younger group reported more hearing difficulties compared to the older group. An interesting implication of this study is that older individuals may not realize the impact a significant HL has on communication.

Objective assessments. Technology may be used to examine a patient's social auditory lifestyle, by examining the noise levels. Tools used to collect objective information may be sound level meters (Wu & Bentler, 2012), sound recorders (Jensen & Nielsen, 2005), and even the microphones from hearing aids can ascertain with what noise environments the patient has been in recently. According to Wagener, Hansen, and Ludvigsen (2008), there is little published information available regarding the acoustic environments hearing-impaired individuals interact in. So, they were prompted to collect data from hearing aid users on their daily environments. Some of the data they gathered were what acoustic situations they are in and how often they are exposed to these signals. There were 20 subjects, ranging in age (18-80 years), and they were all experienced hearing aid users. Subjects used microphones positioned near the microphones of their behind-the-ear hearing aids and portable digital audiotapes to record their everyday situations. Within each situation, they were instructed to use their recorder for 5-10 minutes to capture the moment. For each subject, the sound samples were collected onto a compact disc and they were required to describe their recorded situations via a questionnaire adapted from the Glasgow Hearing Aid Benefit Profile questionnaire. Acoustic analysis showed "...that the importance, problems, and hearing aid benefit as well as the acoustic characteristics of the individual situations vary a lot across subjects" (2008). Overall, this study showed how relatively easy it is for people to record their auditory environments and interventions should be adjusted to fit everyone's personal lifestyle.

Auditory lifestyle in hearing impaired older adults

In order to obtain objective evidence based on the hearing demands of elderly individuals with hearing loss, many studies have been conducted. The purpose of Wu and Bentler's (2012) study was to compare the auditory lifestyles of younger and older impaired listeners, and to compare the relationships of age, social lifestyle, and auditory lifestyle. There were 27 subjects (aged 40-88 years) with a sloping high-frequency sensorineural HL. Their auditory lifestyles were objectively measured with a dosimeter, which they used continuously for 14 hours each day for a week. The dosimeter was set to a timer where it would automatically record from the morning and it would switch off at night. Personal journals were also utilized by the subjects to describe their auditory environments being recorded throughout the week. They also completed the Auditory Lifestyle and Demand Questionnaire (ALDQ), which subjectively quantified their auditory lifestyles. Their social lifestyles were also assessed with the Social Network Index, the Welin Activity Scale, and the Social Convoy Questionnaire. Primary findings showed older listeners regularly had quieter auditory and social lifestyles. Also, the authors noted"...social lifestyle, rather than age, is likely a better predictor of listening demand" (Wu & Bentler, 2012).

Depression. This is another factor believed to cause people with a hearing loss to withdraw from social activities. Herbst and Humphrey (1980) presented that 69% of their respondents who had a deaf (profound hearing loss) were also depressed. Managing these two conditions could definitely cause someone to feel isolated. Li et al. (2014) utilized 18,318 adult participants that were involved in the National Health and Nutrition Examination Survey

(NHANES). The 9-Item Patient Health Questionnaire (PHQ-9) scale was administered to assess for depression. Hearing impairment was quantified through self-reports and audiometric testing for adults 70 years or older. Results showed a strong association between hearing loss and depression, more so for women and people under 70 years old. It is important for professionals to be aware of this relationship. Taking this factor into consideration will enable patients to find the care they need within all aspects of their health.

Hearing aids. Auditory ecology has been evaluated numerous times in hearing aid studies. Researchers are curious on how this input may affect various device fittings, technology, and more. Gatehouse, Elberling, and Naylor (1999) explain that different patients may prefer varying processing schemes based on their needs, and being able to identify someone's impaired pscyhoacoustical functions (e.g. listening demands) will also help in selecting the appropriate fitting algorithm to be chosen. Another way to gather information of a patient's auditory ecology is through their own experiences. Jensen and Nielsen (2005) gathered 18 established hearing aid users, had them record their listening environments using a portable recorder, and compare this data to the subjects' own personal descriptions of what they were experiencing. On average, the subjects had a sloping moderate sensorineural hearing loss, without asymmetry between the ears. Also, all subjects had reported satisfaction with their hearing aids prior to the study. The Hearing Aid Performance Questionnaire (HAPQ) and ALDQ were administered to assess the subjects' subjective opinion of the hearing aids and auditory lifestyle. Conventional audiometric testing was also utilized, along with word recognition in noise testing via the Dantale II sentence test. An objective personality test (NEO PI-R) measured five domains of personality: extraversion, agreeableness, neuroticism, openness, and conscientiousness. The subjects recorded their various listening situations with microphones attached to their hearing aids and a portable MiniDisc recorder. Situations were recorded for 2 minutes, but they were not limited to the number of recordings needed. While recording their listening environments, subjects' filled out a specially-developed questionnaire that categorized the type of environment they were in. Results of this study confirmed the subjects were doing acceptable with their hearing aids. ALDQ scores revealed the subjects had rich auditory lifestyles and the majority considered situations that occurred most often as priority. Also, the subjects' personality scores were considered normal. Sound recordings showed 60% of situations included speech, which showed their importance in ranking. However, the type of speech that was considered important for each subject varied, such as group or one-on-one conversations. Active versus passive communication was for the majority more imperative. Overall, this study showed how auditory ecology encompasses speech understanding, but these situations will vary greatly from person to person.

Another study has shown the benefit of comparing auditory ecology to hearing features. Gatehouse, Naylor, and Elberling (2006) examined candidature of 50 subjects for linear, slow-acting automatic volume control (AVC) versus fast-acting (wide dynamic range compression) WDRC hearing aids within-subject, within-device crossover design. Audiometric testing, uncomfortable listening levels, spectro-temporal and masking abnormalities, cognitive tests, self-reports, and acoustic measures of auditory ecology were used. Results revealed AVC and WDRC fittings could definitely vary in benefit when it came to the patient's auditory ecology. For example, listeners who interacted in less varying acoustic environments had higher self-rate scores (listening comfort, satisfaction, and speech intelligibility) when using linear algorithms. It was noted that candidature relies on more than just these measures of auditory/cognitive function and auditory ecology.

Summary

Longer life expectancies are contributing to an ever-growing elderly population. Changes in hearing sensitivity occur with aging and it is a proposed factor for decreased social auditory lifestyles. Numerous theories on aging have been consulted regarding this issue. Disengagement theory explains that a decrease in social activities may be due to a dual withdrawal of the elderly from society and society from the elderly. Social pattern studies have confirmed less listening demands for the elderly versus younger listeners, but it is always important not to assume this is true for all individuals. Being able to evaluate social auditory lifestyles will provide valuable information for choice of device technology, fitting algorithms, rehabilitation interventions, and more.

Conclusion

The purpose of this study was to highlight the need for future research regarding an association between hearing loss, cognition, and social auditory lifestyle. An age-related hearing loss is known as the most frequent sensory deficit of the elderly (Huang & Tang, 2010). The effects of this condition are at times largely underestimated. Aging initiates a copious amount of changes, both physical and psychosocial. An ARHL has been shown to be associated with cognitive decline (Lin, 2011a). Symptoms of this may include memory, orientation, and speech perception deficits. Specifically, dementia and Alzheimer's disease are common forms of cognitive decline seen within this population (World Health Organization, 2017). Meanwhile, individuals with a hearing loss have been linked to have a reduced social auditory lifestyle (Wu and Bentler, 2012). The exact cause of this trend has yet to be discovered, but the reason is greatly varied when examining a group on an individual basis.

The intricate relationship between hearing loss, cognition, and social auditory lifestyle continues to be deciphered. Pichora-Fuller et al. (2016) focused their research on how hearing impairment relates to cognitive energy. The authors created a Framework for Understanding Effortful Listening (FUEL) by assimilating the relationship between cognitive demand and the supply of cognitive capacity. FUEL was adapted from Kahneman's (1973) Capacity Model of Attention, which proposes how the brain allocates its resources to "available capacity." This allocation may be affected by the relevance of the message, possible multitasking occurring while listening, evaluating demands, and state of arousal. It would appear that having a hearing loss can contribute to the allocation of cognitive energy to areas outside of the auditory system, which then may negatively affect overall cognition (Jayakody, Friedland, Martins, & Sohrabi, 2018). Lin et al. (2013) showed an independent relationship between hearing loss and cognitive decline, and suggested this could lead to social isolation. In regards to social lifestyle and cognition, Bennett et al. (2014) found only a small direct relationship between the two. It seems both cognition and social auditory lifestyle contribute to the negative effects associated with hearing loss. Someone coping with all three of these conditions are at risk for having a reduced quality of life. Therefore, a better understanding of this relationship will enable appropriate clinical treatment for this population. Continuing to offer excellent care to the elderly should be of upmost priority as this population will increase significantly in size within the next several decades.

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